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Problems of Interpreting Arthropod Sampling with Pitfall Traps

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Abstract

18 factors which effect pitfall-trapping are described. The value of the sampling results for population-ecological investigations is discussed. Advice for the future use of pitfall traps is given. The combined application of several capture methods is proposed.

Introduction

Pitfall traps (Barber 1931) are favorite 'instruments' to collect invertebrates of the soil surface and of the space near the ground. The sampling results were utilized for drawing conclusions about diurnal activity, annual cycles of activity (Jahresdynamik), intensity of activity (Aktivitätsdichte), dominance of activity (Aktivitätsdominanz), biomass of arthropods on the soil surface as well as fluctuations in their frequencies (Geiler 1055, Greenslade 1964, Heydemann 1953, Mitchell 1963 a, b, Skuhravy 1956 a, b, 1958, Schütte 1957, Tretzel 1955, Weidemann 1971, 1972, Williams 1959 a, b). However, critical investigations show, that the interpretation of the samples is problematical. According to Thomas et al. (1977) problems associated with pitfall-trapping can be placed in 4 categories: 1. "Biases caused by the intrinsic properties of pitfall methodology. 2. Variance due to stochastic processes. 3. Variance due to fluctuations in activity of the population at risk. 4. Variance due to real changes in the abundance of the population."

This paper discusses problems due to the pitfall methodology, including a survey of the existing literature.

Factors influencing sampling effectiveness of pitfall-traps

The following factors influence the sampling effectiveness of pitfall traps:

1. The climatic conditions of the experimental area: Soil humidity, precipitation and temperature affect activity of invertebrates and cause increase or decrease in sample size (Briggs 1961, Duffey 1962, Geiler 1964, Greenslade 1961, Grüm 1959, Kirchner 1964, Lauterbach 1964, Löser 1972, Mitchell 1963 a, b, Stein 1965).

2. The vegetation of the experimental area: Arthropods are somewhat dependent on vegetation (Bombosch 1962, Duffey 1972, Jeschke 1938, Novák 1967 a, Thiele 1964, 1968, Williams 1959 a, b). According to Deseo (1959), the age of the vegetation influences the sampling results. The absence or removal of the herbaceous layer near pitfall traps leads to either an increase or a decrease of the sample size (Greenslade 1964, Novák 1969).

3. Surface irregularities: Substrate irregularities and obstacles such as uneven surface, stones, branches, etc. particularly affect small arthropods and diminish their numbers in the samples (Heydemann 1956 b, Jeschke 1938, Skuhravy 1957).

In forests, the depth of the ground-litter inuflences the sampling results as well (Greenslade 1964, Heydemann 1956 b). The proximity of a shrub to a trap will increase the capture success for some beetles (Ahearn 1971).

4. The diameter of the trap: It has been found that the greater the diameter of the trap, the more invertebrates that will be caught (Heydemann 1958, Novák 1969, Turner 1962, Williams 1968, 1970). However, some groups seem to caught more effectively with small pitfall traps, for examlpe spider and solpugid populations (Gist et al. 1973, Luff 1975, Muma 1970, Schmoller 1971).

5. The form of the trap: As compared to circular traps, quadrangular and rectangular traps may show different sample sizes, depending on their orientation in the soil (Adis 1976, Braune 1974, Luff 1975).

6. The installation of the trap: To collect valid samples of small arthropods the edge of the trap must be level with the soil surface. Excessive inclination of the soil which rings the trap changes the direction of mobile arthropods such that they are not caught (Heydemann 1953). The use of plastic disks which rings the trap entrance, may influence the sample size (Adis 1976).

7. The cover of the trap: Metal and glass covers affect light and microclimate in the area near the trap (Heydemann 1953).

8. The killing-preserving agent used in the trap: Preservative solutions may have an attractive or repellent effect on arthropods: ethylene glycol and formaldehyde solutions (3...5%) are mainly attractive (Adis 1976, Adis et al. 1975, Heydemann 1953, 1956 a, 1958, Luff 1968, Skuhravy 1970), picric-acid solution is mostly neutral, water and alcohols may be repellent (Adis 1976, Southwood 1966).

Methylated spirit seems to be neutral for ants (Greenslade et al. 1971). The attractive or repellent effect of a given killing-preserving agent depends on the species, and even closely related species may show differences in this respect (Adis 1976, Braune 1974, Luff 1968).

The reaction to the solution also depends on sex, and the frequencies of males and females may show considerable differences (Adis 1974), also due to sex pheromones released in the traps (Haverfield 1965). The attractant or repellent effect of killing-preserving agents may vary greatly with season as well (Adis 1976, Adis et al. 1975, Dethier 1947).

It is further noted that:

9. Not all insect species which are active on the soil surface are caught by pitfall traps (for example, some Araneae, Isopoda, Scorpions and Staphylinidae; Albert 1973, Duffey 1962, Hadley and Williams 1968, Hayes 1970, Uetz et al. 1976). This may be due to differences in behaviour (aggregation pheromones, low vagility, permanent refugia and biology (sex pheromones) of some species (Duffey 1962, Mertens et al. 1977, Renwick et al. 1977).

10. Not all arthropods which reach the edge of the trap drop in. Coleoptera frequently hold fast by hooking themselves with their claws on the edge and manage to pull themselves up again. Large Carabidae are more likely to fall into the traps than smaller species due to their greater weight and their higher running speed (Adis 1976, Braune 1974).

11. The numbers of individuals of dominant ($> 5\%$), subdominant ($1...5\%$) and rare ($< 1\%$) species of the experimental area caught in the traps depends on the numbers of pitfall traps (Bombosch 1962, Orbtel 1971, Stein 1965).

12. The manner in which the traps are arranged with respect to each other and the distance between the traps influences the sample sizes (Adis 1976, Ahearn 1971, Heydemann 1953, Stein 1965, Uetz et al. 1976).

13. Pitfall trap efficiency may depend not only on size and shape, but also on the material of which the trap is made (Luff 1975).

14. Arthropods of different groups are able to escape from pitfall traps (Luff 1975, Petruska 1969). Traps with a somewhat constricted entrance complicate the escape of species which are good climbers (Heydemann 1953). Yogurt cups are not suitable for pitfall-trapping (Adis, unpublished data).

15. In a capture-recapture study using a 4 m^2 raised wooden platform covered with ground litter, more arthropods were caught in traps situated near the edge and in the corners of the platform than in traps situated more centrally (Adis 1976).

16. As a consequence of the "digging-in" effect, Formicoidea and Collembola show intensified activity which lead to higher sample sizes (Joose et al. 1968, Greenslade 1973).

17. Walking over the experimental area leads to an increase of the CO_2 content within the soil, which intensifies activity of the Collembola and thus leads to higher sample sizes (Joose et al. 1968).

18. Using the capture-recapture method, Coleoptera may become "trap-happy", prefering dry pitfall traps as refugia (Thomas et al. 1977). To fence or enclose an area (= a population) may produce a bias, the so called "Kreb's effect" (Mac Arthur 1972).

For all these reasons the results of pitfall-trapping may not be wholly representative of the real situation and their interpretation is therefore difficult.

Pitfall traps are mainly used for population-ecological investigations. Nevertheless, the results of pitfall catches do indicate the characteristic phenophases of the arthropods, annual periodicity of activity, and the temporal pattern of dispersal. Samples of pitfall traps also give information on the species composition of a community and allow relative comparision between different areas of a habitat within the same sampling period.

Advice for investigations using pitfall-traps

For investigations with pitfall-traps, the following advice is given:

I. Field-investigations

a) Species-Inventory of a community

To arrive at a better inventory of the species of a community, heterogenous catch conditions should be used: various forms of pitfall traps with different diameters and various killing-preserving agents and baits; furthermore, the arrangement of, and the distance between, the trap should vary. Collections should be made over a long period of time (i.e. spring until autumn) and, if not possible, at least several times for a small period of time (not less than 4 weeks) within

different seasons (i.e. spring, summer, autumn). These trap periods must be of the same length (= number of trap days).

The simultaneous use of other sampling methods is recommended.

b) Other population-ecological investigations (relative abundance, activity, temporal pattern of disperseal etc.)

1. trap period: Only long-term trapping (Muma 1975) should be applied (i.e. whole seasons).

2. trap type: Should be similar to the original Barber trap (see Balogh 1958: diameter 5,6 cm, depth 12 cm (not less), circular, constricted entrance, glass or plastic-sided), until a standard trap size is introduced.

3. trap cover: Transparent plastic covers should be used, metal or glass covers avoided. To diminish reflections, the trap cover should be painted with a mixture of colourless mat paint and sand (see Adis 1976).

4. trap installation: Traps should be level with the soil surface and ringed by soil, not by plastic or metal material (rings, lids, disks etc.). The use of plastic tubes which line pitfall traps and pitfall holes in the soil are recommended.

5. killing-preserving agent: The use of dry pitfall-traps, including the capture-recapture method without fence (see Thomas 1977) is preferable. If not possible, the mostly not attractive and not repellent picric-acid solution (1 part saturated picric acid solution to 3 parts of water) should be used, until other agents are sufficiently tested.

6. control-time: Dry pitfall traps should be checked daily; picric-acid solution should be changed 2...4 times a month, dependent on climate and location. Walking on the experimental area should be kept to a minimum.

7. trap number: Depends on the environment, 24...36 Barber traps (diameter 5,6 cm) are normally sufficient for dominant and subdominant species of groundsurface-dwelling arthropods. In case of doubt, a species-area curve should be made (see Uetz et al. 1976).

8. trap arrangement: According to the literature, arrangement in a line is preferable.

9. trap distance: Depends on the environment and the object under study. (Should be less than the distance traveled by an individual of the population at risk during a trap period). For general investigations, 1...2 m are advised for Barber traps, with a control time of 7 days.

II. Evaluation of field investigations, depending on pitfall methodology

1. Statements based on pitfall-trapping should include a detailed description of which type of trap (size, material, cover etc.), killing-preserving agent, and trap-arrangement have been used.

2. Investigations depending on pitfall methodology should include a detailed account of the plant cover and vegetation structure in the catching area.

3. Trap records exclusively based on pitfall methodology and not guided by a knowledge of the biology (life cicle, food habits etc.), ecological requirements and behaviour of target species could be misleading.

4. Statements on absolute values concerning dominance of activity (Heydemann 1953) are, in my opinion, not possible.

5. To estimate population densities with the capture-recapture method (using dry pitfall traps) the application of the 'Jolly model' or 'geometric model' is proposed (see Jolly 1965, Thomas et al. 1977).

6. Relative comparisons between communities from one area but from different years, months or seasons are possible but must be interpreted with caution. It is essential that type and arrangement of the traps be identical. The influence of changing habitat factors (climate, vegetation etc.) has to be taken into consideration. Statements on the list of species and the intensity of activity comparing different habitats and different years, months or seasons (Novák 1967 b, Petruska 1967) are problematical and should only be made with the greatest caution.

7. In general, comparisons with results already presented in the literature are extremly difficult. Nearly all investigations thus far have been conducted in different habitats, during different seasons, with different arrangements and types of the traps and with various killing-preserving agents (see Bomborsch 1962, Muma 1975).

8. Because pitfall-trapping is influenced by so many factors and not uniformly applicable to all species of ground-surface-dwelling arthropods, the combined use of several capture methods (compare Uetz et al. 1976) is indispensable in obtaining 'relative and absolute characteristics of the arthropod fauna' (Balogh 1958) in the ecosystem under study. For forest ecosystems the 'Minimal programme for an ecosystem-analysis' worked out by Grimm et al. (1975) is recommended.

Conclusions

So far, more pitfall traps have been invented than a scientist can use during his life and a standard pitfall trap is badly needed. Efforts should be made by international Ecological and Entomological Societies to set up a pitfall trap test-center, where serious laboratory and field tests with already used pitfall traps can be made and a standard pitfall trap for future use can be developed. This test-center could also solve the still open question of whether the ordinary Barber traps has to be replaced by new traps, as for example by a long strip pitfall trap (a plastic drainpipe split in half longitudinally) as suggested by Greenslade (unpubl.) or by a pitfall trap on the soil surface, as used by Goulet (unpubl.).

At present, trap types similar to the original Barber traps, with constructed entrances, should be used, to permit more accurate comparisons of arthropod communities in the future.

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